N91-27288

Program 3 **Temperature Effects on the Deformation and Fracture of Al-Li-Cu-In Alloys**

John A. Wagner and R.P. Gangloff

P29

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Objective

The objective of this PhD research is to characterize and optimize the crack initiation and growth fracture resistance of Al-Cu-Li and Al-Cu-Li-In alloys for cryogenic tank applications. The program aims to understand microscopic fracture mechanisms, as influenced by ambient to cryogenic temperature, stress state and microstructure.

Fracture of 2090 and 2090+In Alloys at Cryogenic Temperatures

John A. Wagner and R.P. Gangloff

The objective of this program is to understand, characterize and optimize the crack initiation and growth fracture resistance of Al-Cu-Li and Al-Cu-Li-In alloys for cryogenic tank applications. Presently, this work is concentrating on determining the effects of stress state and temperature on the fracture toughness and fracture mechanisms of commercially available Vintage III 2090-T81 and experimental 2090+In-T6. Precracked J-integral specimens of both alloys have been tested at ambient and cryogenic temperatures in the plane stress and plane strain conditions. Considering ambient temperature, results showed that 2090-T81 exhibited the highest toughness in both plane strain and plane stress conditions. For the plane strain condition, reasonable crack initiation and growth toughnesses of 2090-T81 are associated with a significant amount of delamination and transgranular fracture. Plane stress toughnesses were higher and fracture was characterized by shear cracking with minimal delaminations. In comparison, the fracture behavior of 2090+In-T6 is significantly degraded by subgrain boundary precipitation. Toughness is low and characterized by intersubgranular fracture with no delamination in the plane stress or plane strain conditions. Intersubgranular cracking is a low energy event which presumably occurs prior to the onset of slip band cracking. Copious grain boundary precipitation is atypical of commercially available 2090. At cryogenic temperatures, both alloys exhibit increased yield strength, toughness and amount of delamination and shear cracking. The change in fracture mode of 2090+In-T6 from intersubgranular cracking at ambient temperature to a combination of intersubgranular cracking, shear cracking and delamination at cryogenic temperature is the subject of further investigation.

FRACTURE OF Al-Li ALLOYS 2090 AND 2090+In AT CRYOGENIC TEMPERATURES

John A. Wagner

LA^2ST Program Review

NASA Langley Research Center

July 9-10, 1991

FRACTURE OF 2090 AND 2090+In ALLOYS

Problem

- No systematic investigation conducted to determine the interactive effects of:
  - Temperature
  - Delamination
  - Indium addition
  - Microstructure

  on the fracture of 2090-based alloys

Objective

- Determine the influences of intragranular features & grain boundary structure in governing the occurrence of various fracture mechanisms in Al-Li-Cu-X alloys at ambient and cryogenic temperatures.

FRACTURE OF 2090 AND 2090+In ALLOYS AT CRYOGENIC TEMPERATURES

Outline

- Summary of initial experimentation (sheet)
- Progress on plate material testing
- Future Direction

INDIUM ADDITIONS TO 2090-BASED ALLOYS

Sheet Product Form

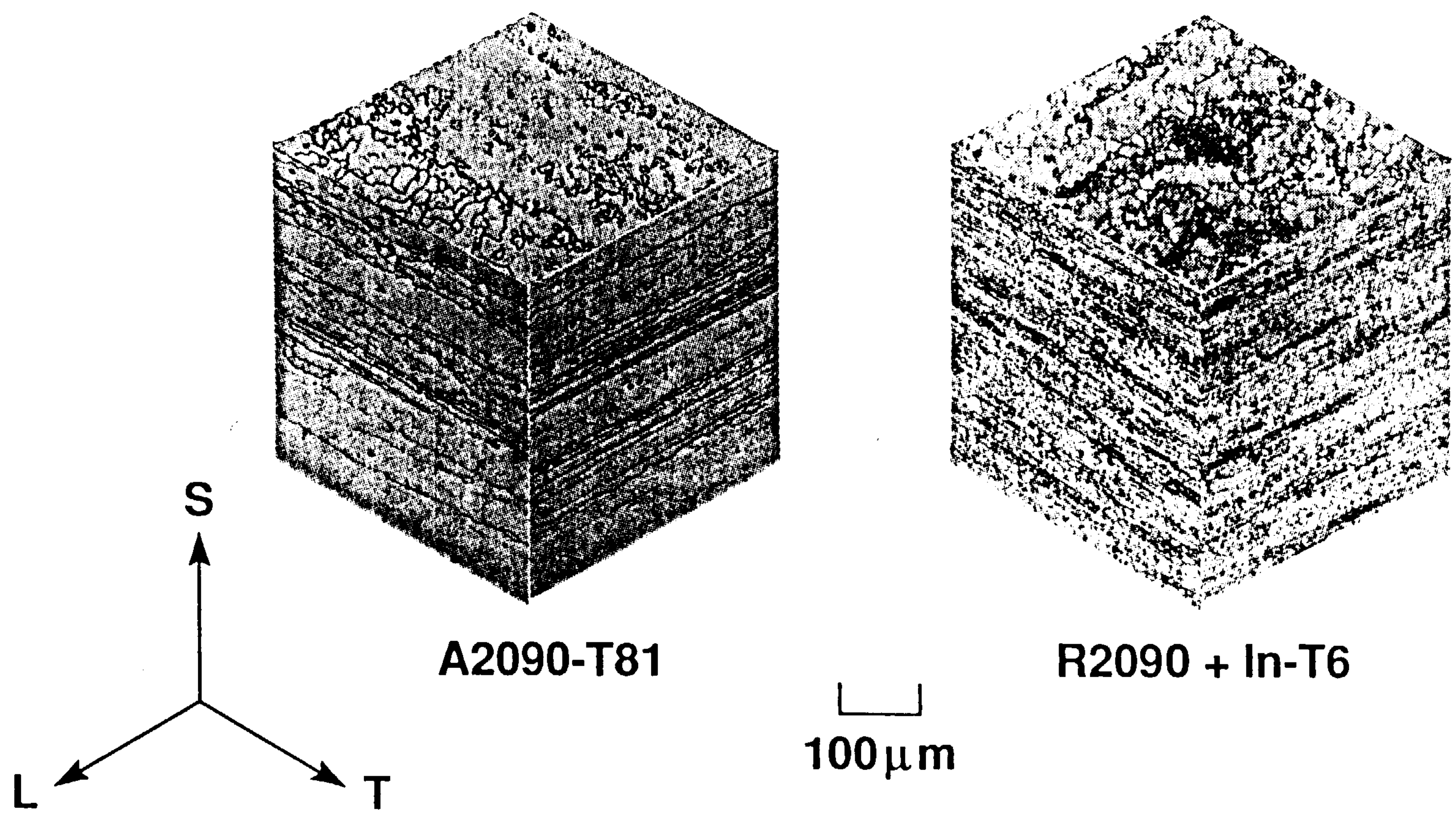
Observations

- Increased in σ_{ys} + σ_{ult} observed for 30 lb laboratory permanent mold casting attributed to increase number density of T_1
- For 350 lb DC castings indium additions increased σ_{ult} but had no effect on σ_{ys} regardless of product form
- Fracture of 2090+In alloy primarily characterized by intersubgranular failure
- TMT used to render 2090+In superplastic complicated interpretation of results

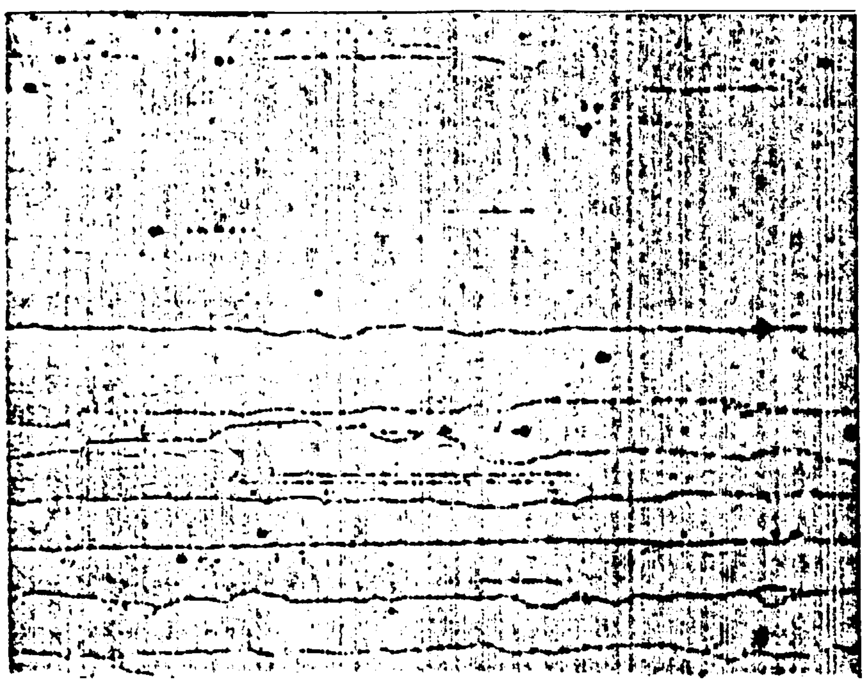
OBJECTIVES OF EXPERIMENTAL TESTING OF PLATE MATERIAL

- Determine the effect of key variables on J (Δ a) behavior, fracture path and fracture mode of 2090 and 2090+In alloys with respect to
  - Temperature
  - Constraint
  - In addition
  - Material vendor
  - Orientation

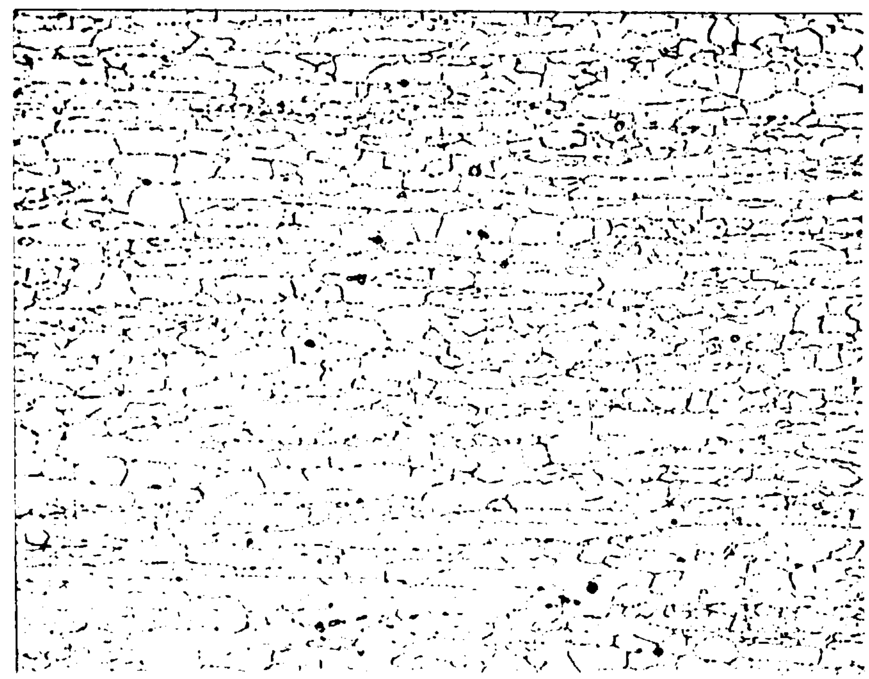
MICROSTRUCTURES OF PLATE ALLOYS



COMPARISON OF SUBSTRUCTURE PRECIPITATION OF A2090-T6 AND R2090-T6 AGED 20 HRS AT 160°C



A2090-T6

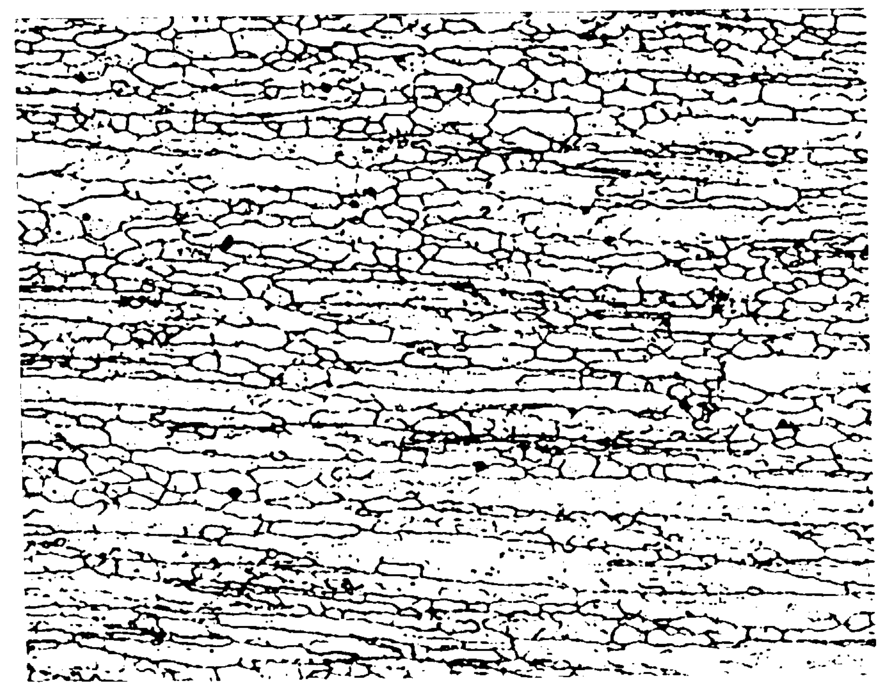


R2090+In-T6

25μm

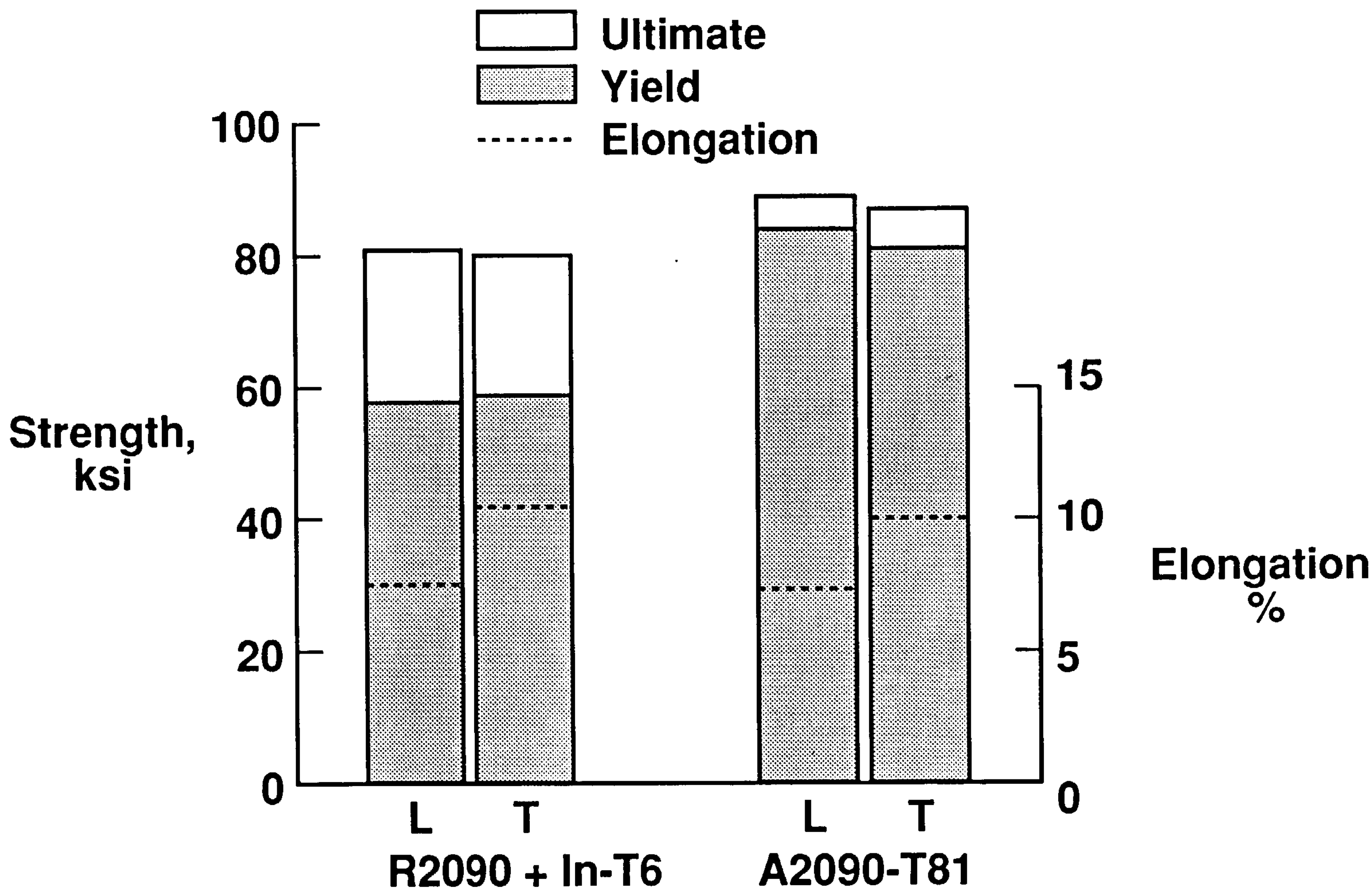
COMPARISON OF LABORATORY HEAT TREATMENTS AND QUENCH RATES ON 2090+In

Reynolds Metals
SHT = 555°C, 0.5 hrs
Age = 160°C, 72 hrs
Cold water quench

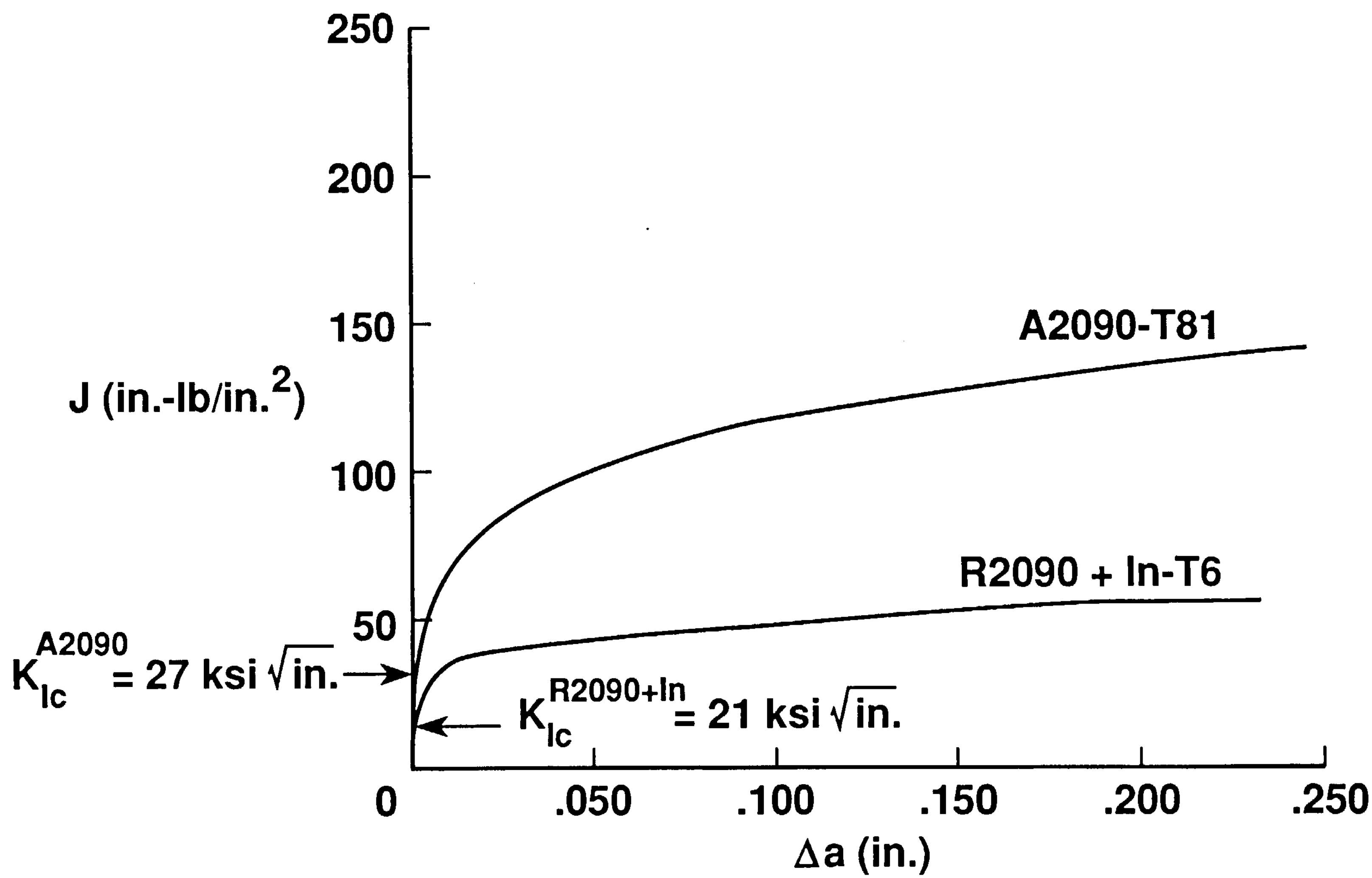


NASA LaRC
SHT = 560°C, 0.5 hrs
Age = 160°C, 72 hrs
Ice brine quench

TENSILE PROPERTIES 2090 AND 2090+In ALLOYS

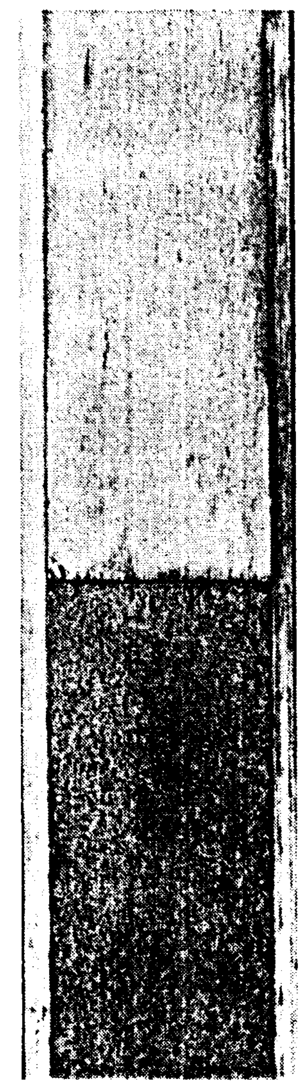


FRACTURE TOUGHNESS R-CURVE FOR 0.47" THICK SPECIMENS WITH SIDEGROOVES AT ROOM TEMPERATURE



FRACTURE MORPHOLOGY OF 0.47" THICK COMPACT TENSION SPECIMENS AT ROOM TEMPERATURE

A2090-T81

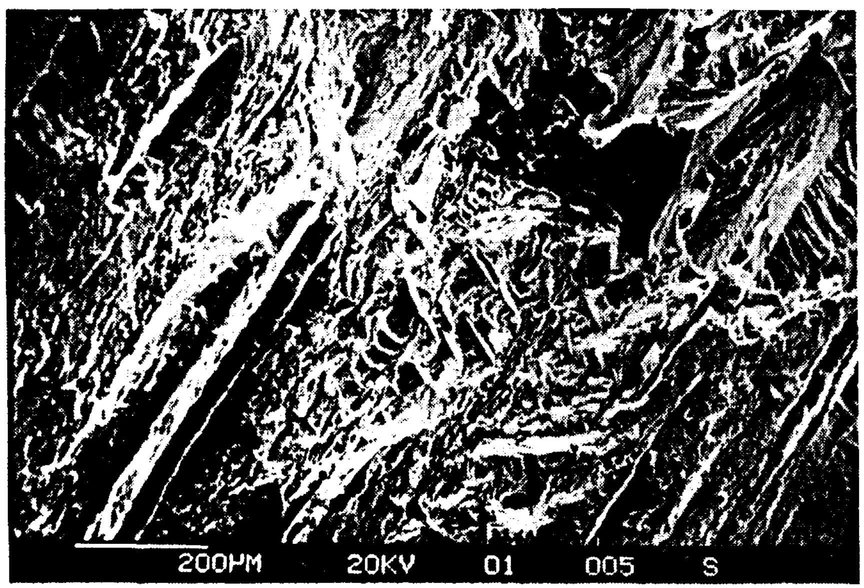


R2090 + In-T6

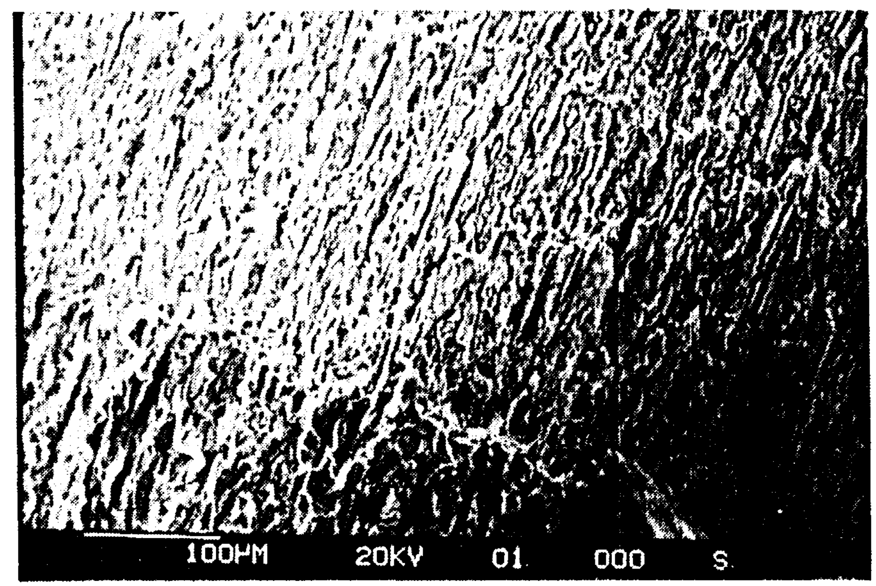
A2090-T81

R2090 + In-T6

FRACTURE SURFACE MORPHOLOGY OF PRE-CRACK/FAST FRACTURE TRANSITION REGION

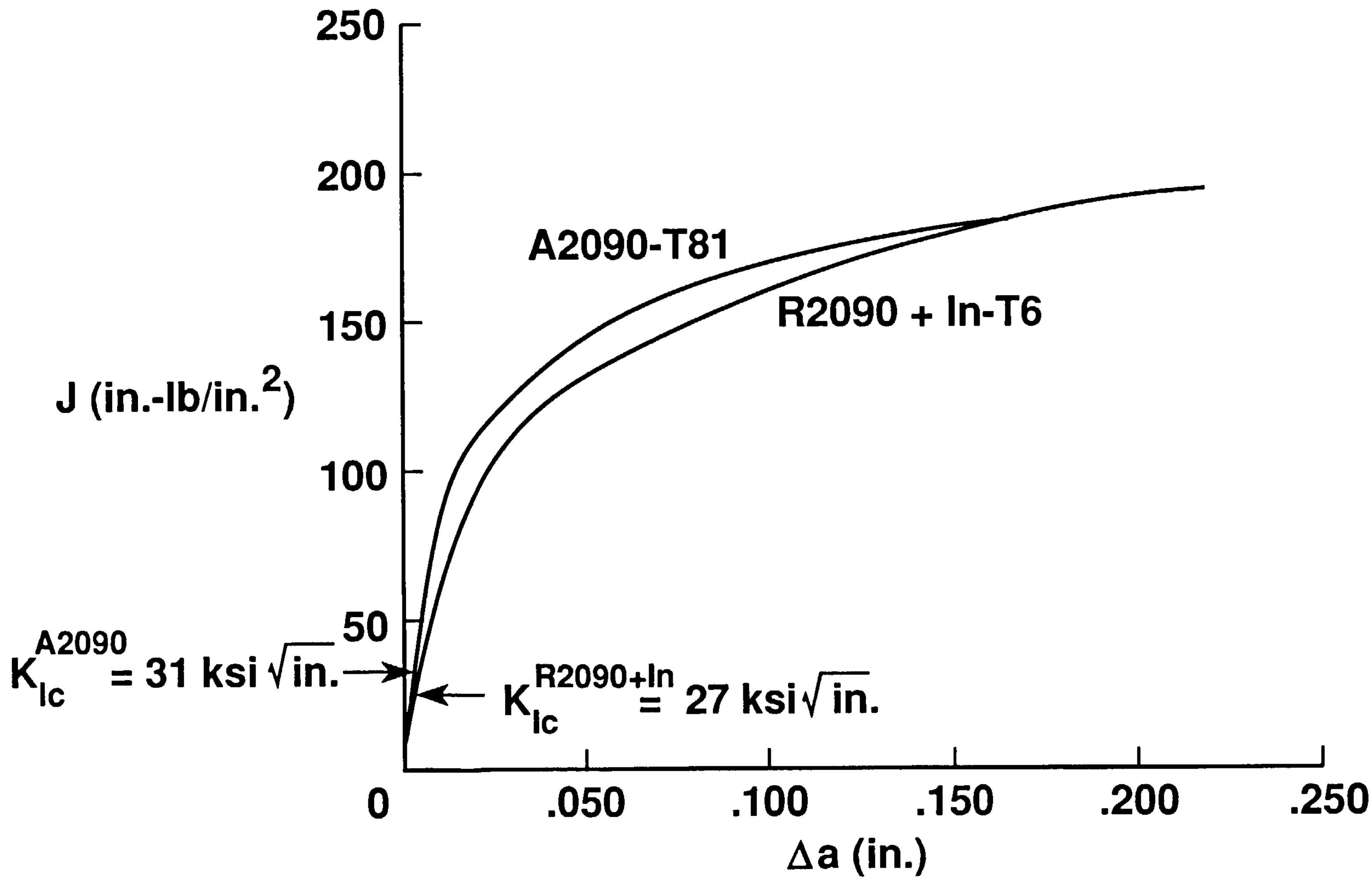


A2090-T81



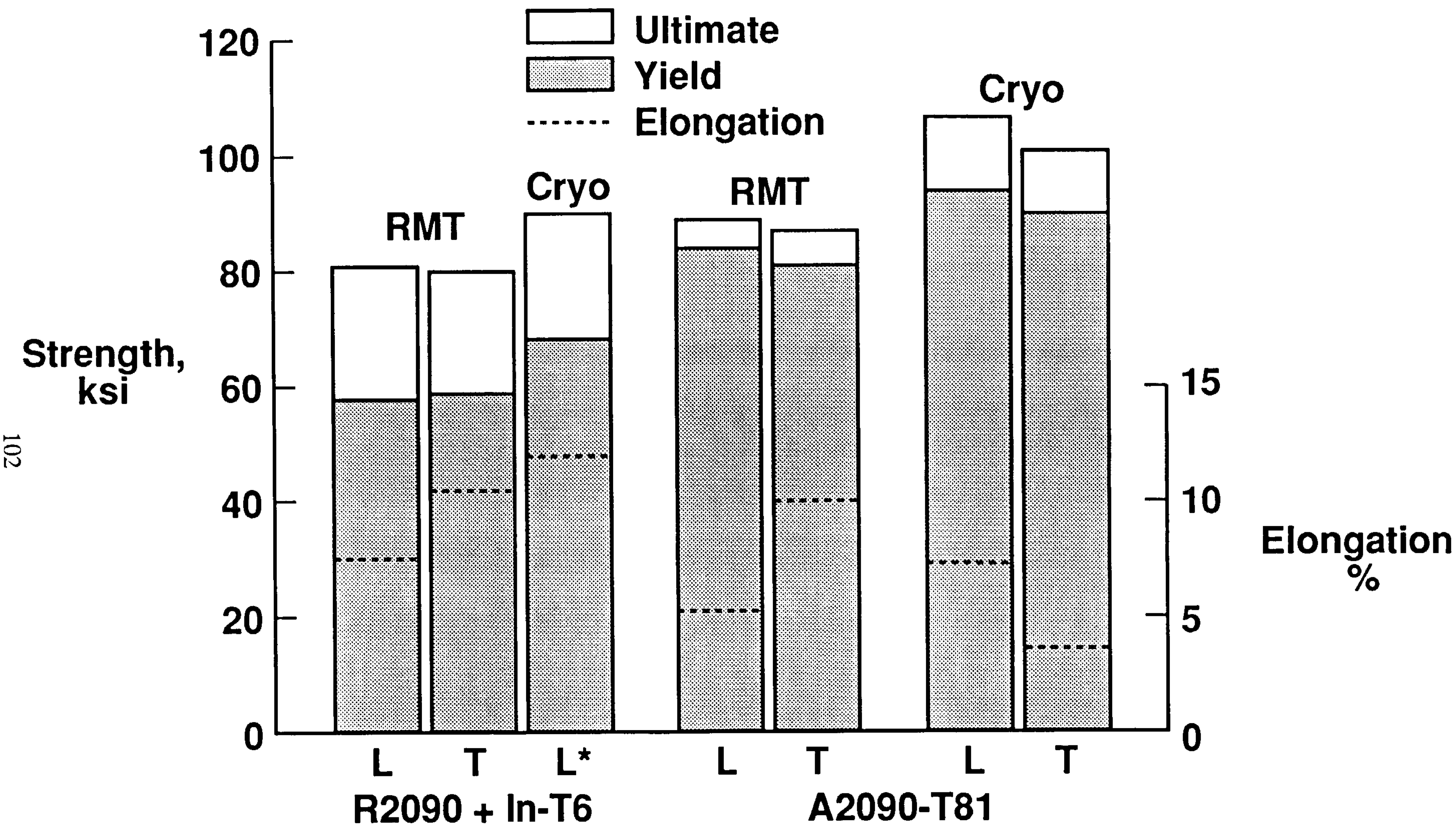
R2090 + In-T6

FRACTURE TOUGHNESS R-CURVE FOR 0.06" THICK SPECIMENS AT ROOM TEMPERATURE



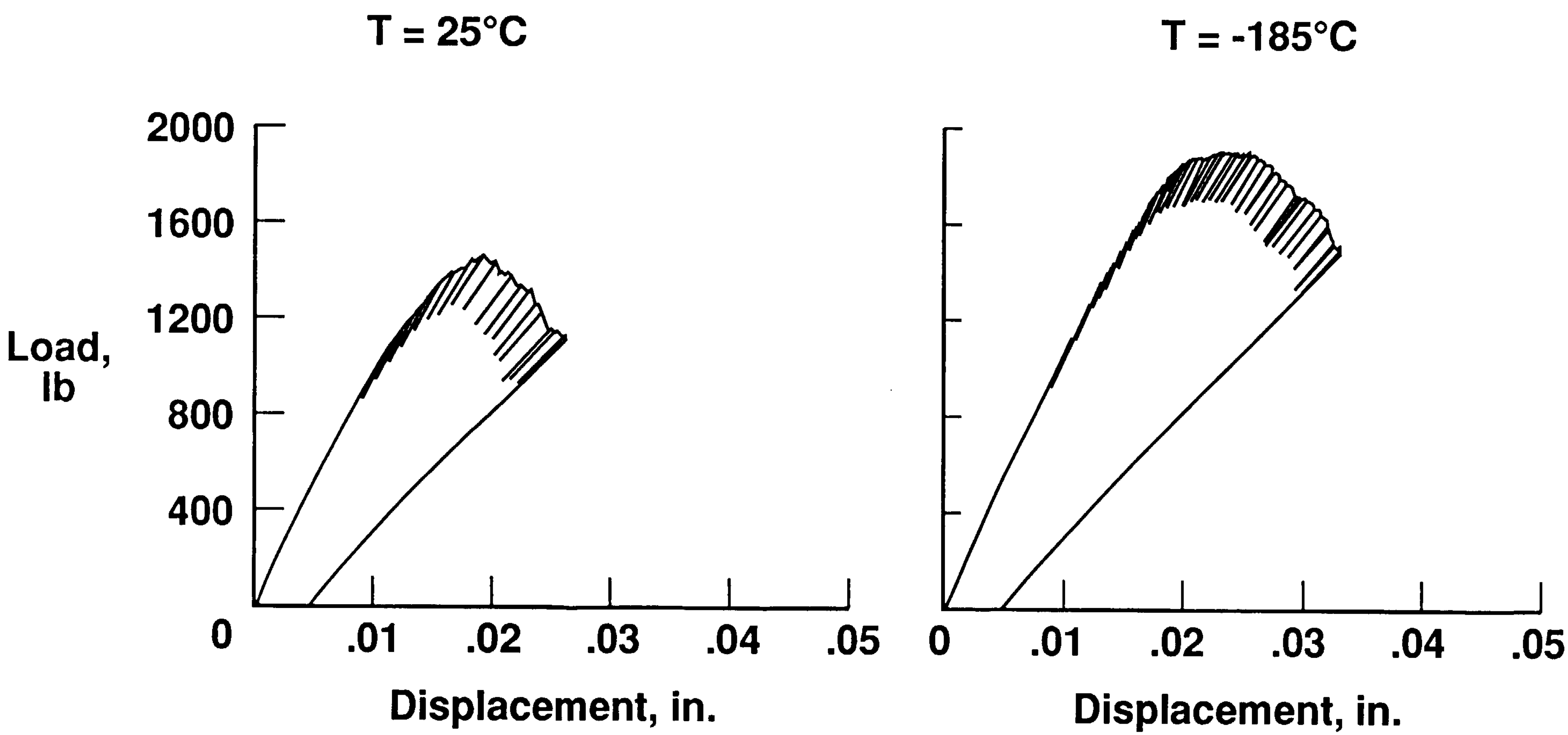
TESTING AT CRYOGENIC TEMPERATURES

TENSILE PROPERTIES 2090 AND 2090+In ALLOYS



* Extrapolated from sheet cryoproperties

LOAD VERSUS DISPLACEMENT CURVES FOR 0.473 IN. 2090-T81 SPECIMENS AT 25°C AND -185°C

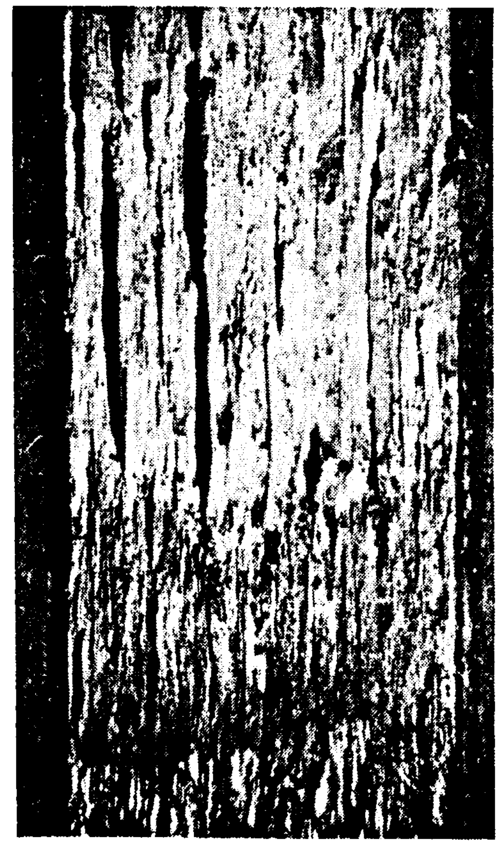


lvsdc/3

FRACTURE SURFACE OF 2090-T81 AT ROOM AND CRYOGENIC TEMPERATURES

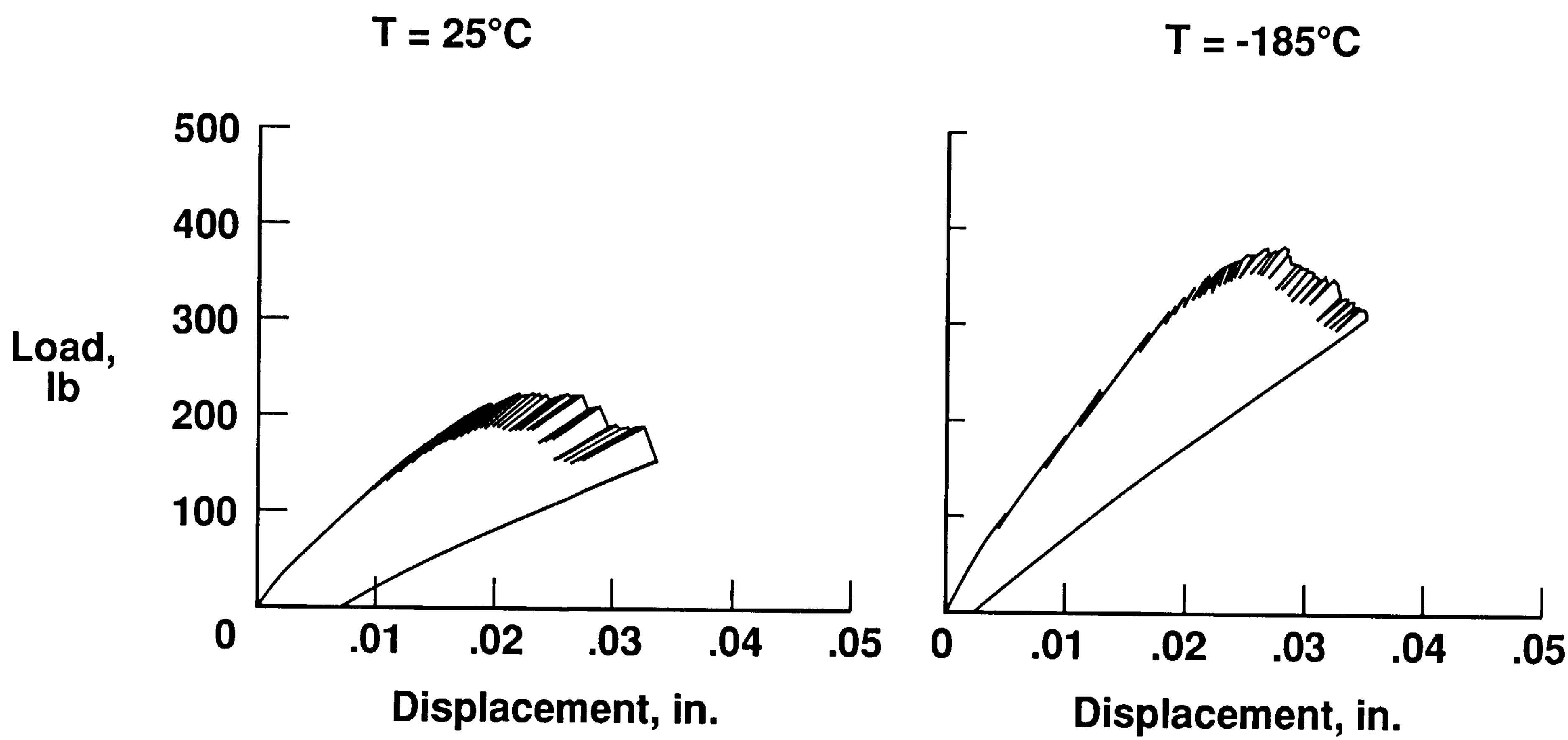
B = 0.47 in. with sidegrooves

T = 25°C



T = -185°C

LOAD VERSUS DISPLACEMENT CURVES FOR 0.063 IN. 2090-T81 SPECIMENS AT 25°C AND -185°C



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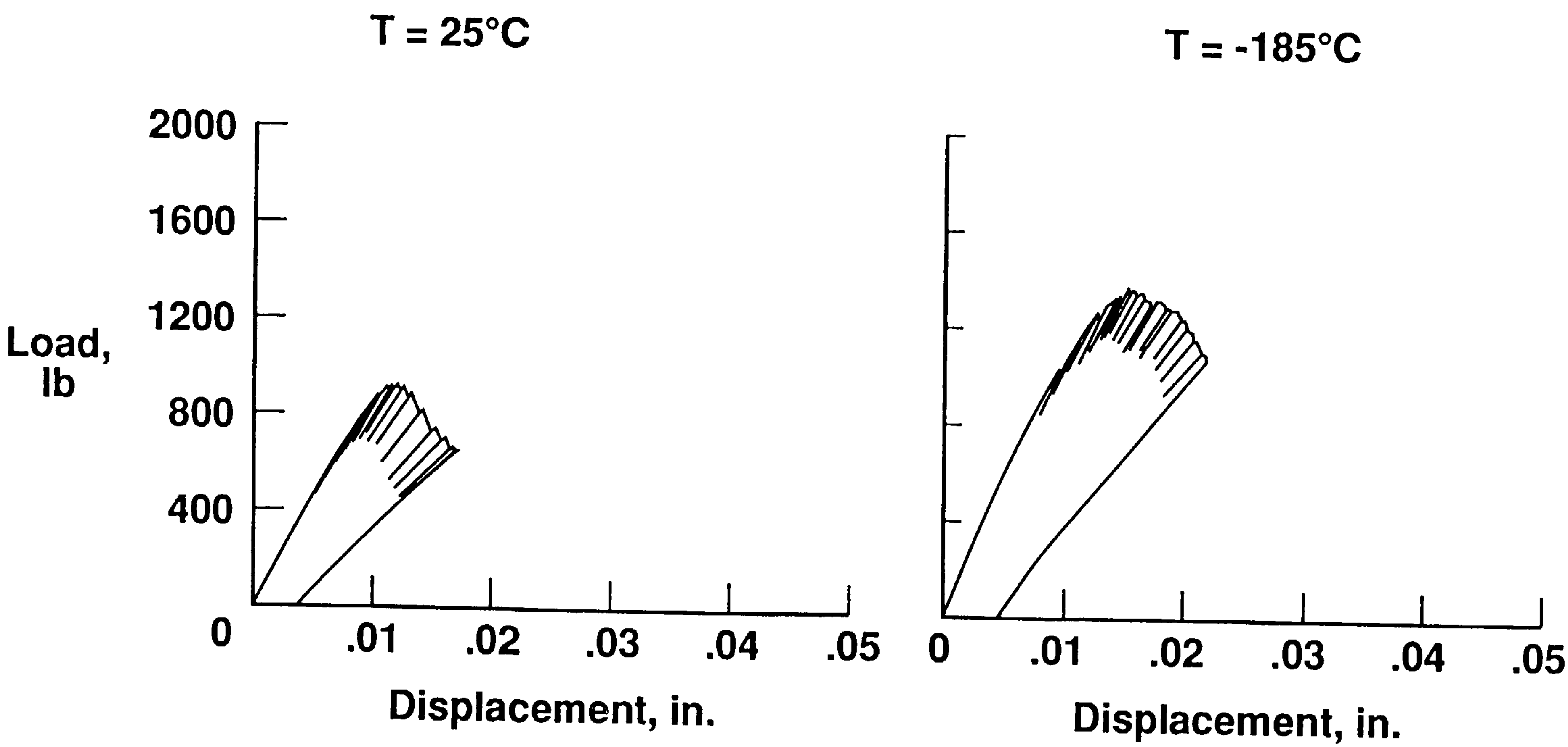
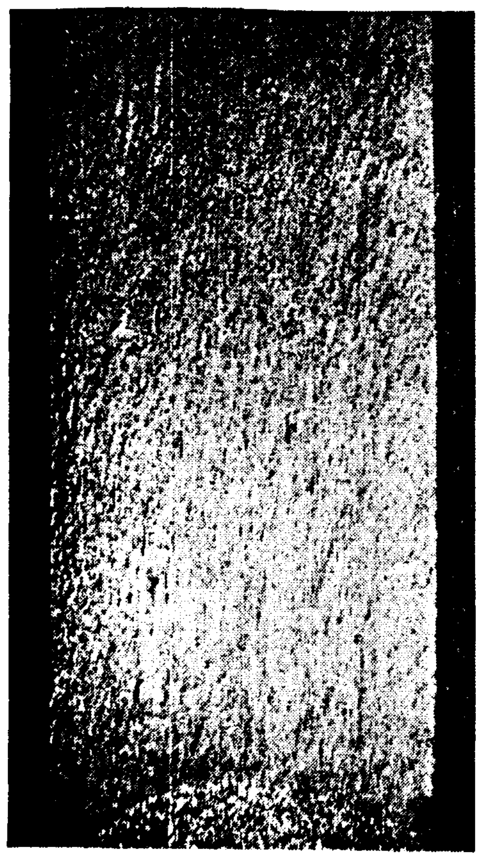
LOAD VERSUS DISPLACEMENT CURVES FOR 0.473 IN. 2090+In-T6 SPECIMENS AT 25°C AND -185°C



FRACTURE SURFACE OF 2090+In-T6 AT ROOM AND CRYOGENIC TEMPERATURES

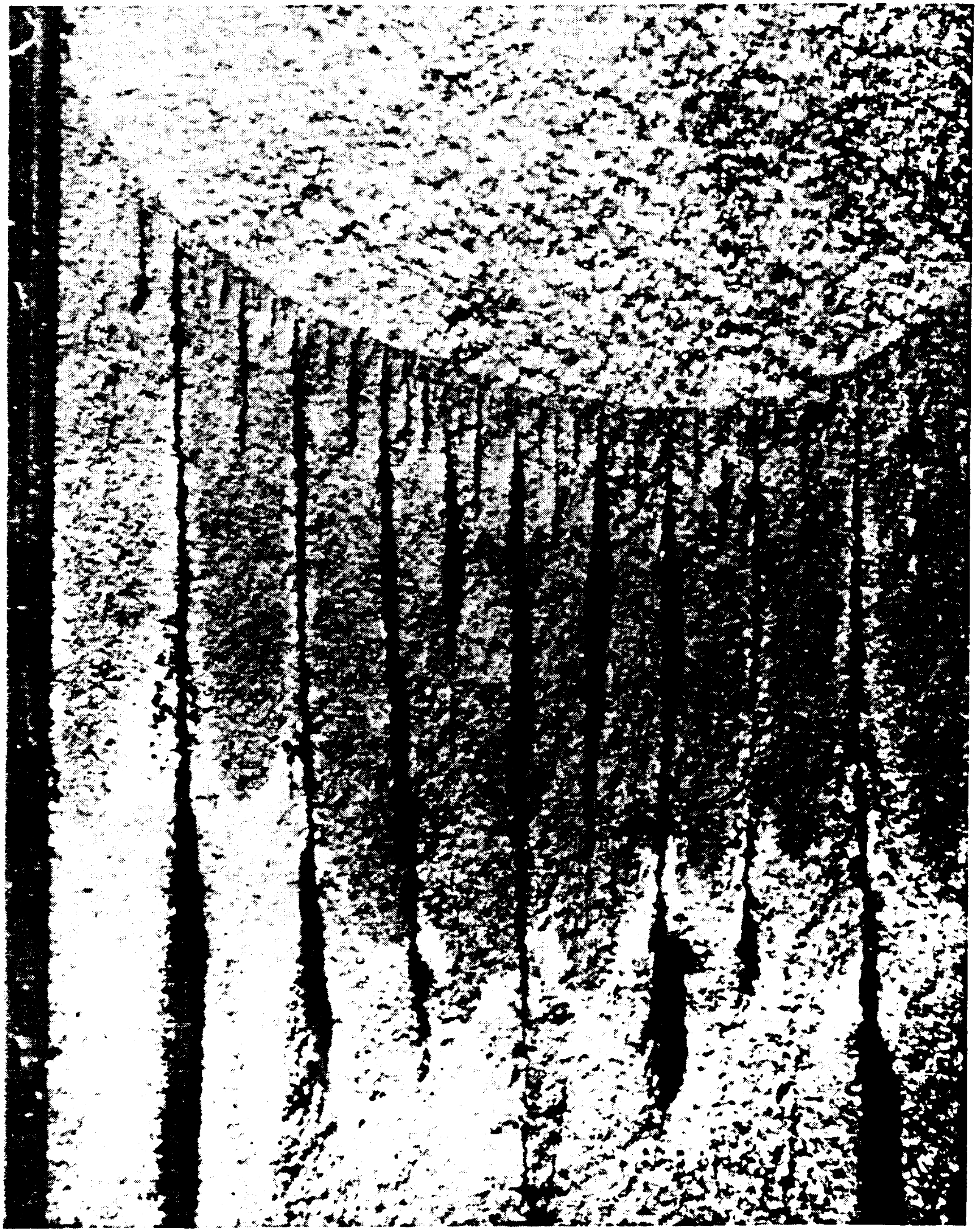
B = 0.47 in. with sidegrooves



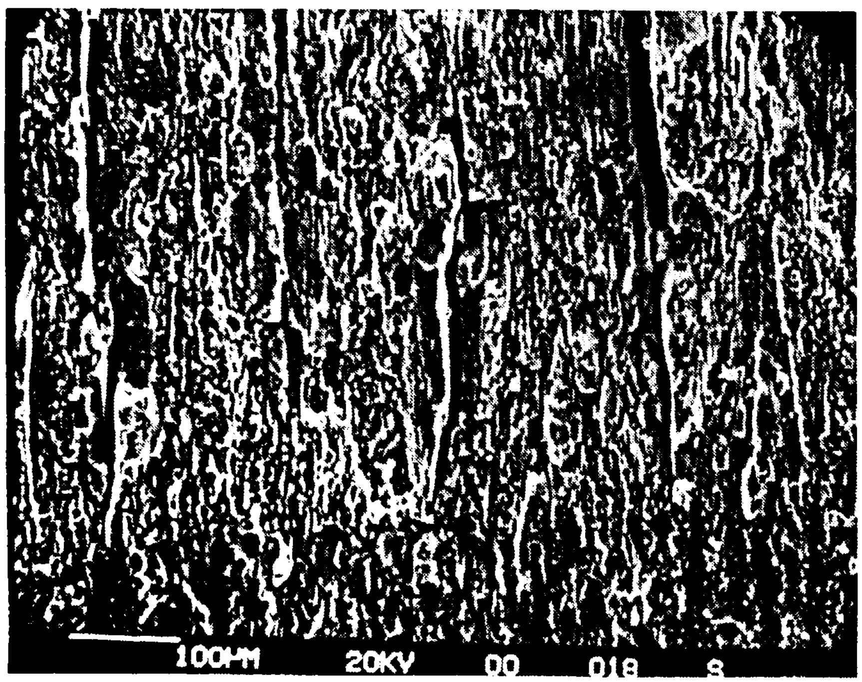
T = 25°C

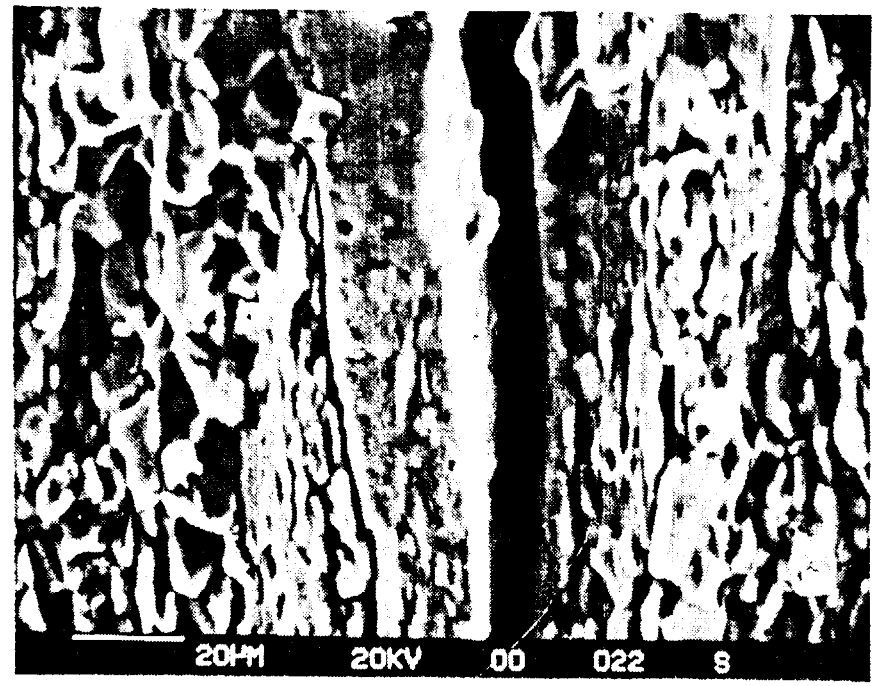
T = -185°C

FRACTURE SURFACE OF 2090+In-T6 AT -185°C



FRACTURE SURFACE MORPHOLOGY OF 2090+In-T6 AT -185°C





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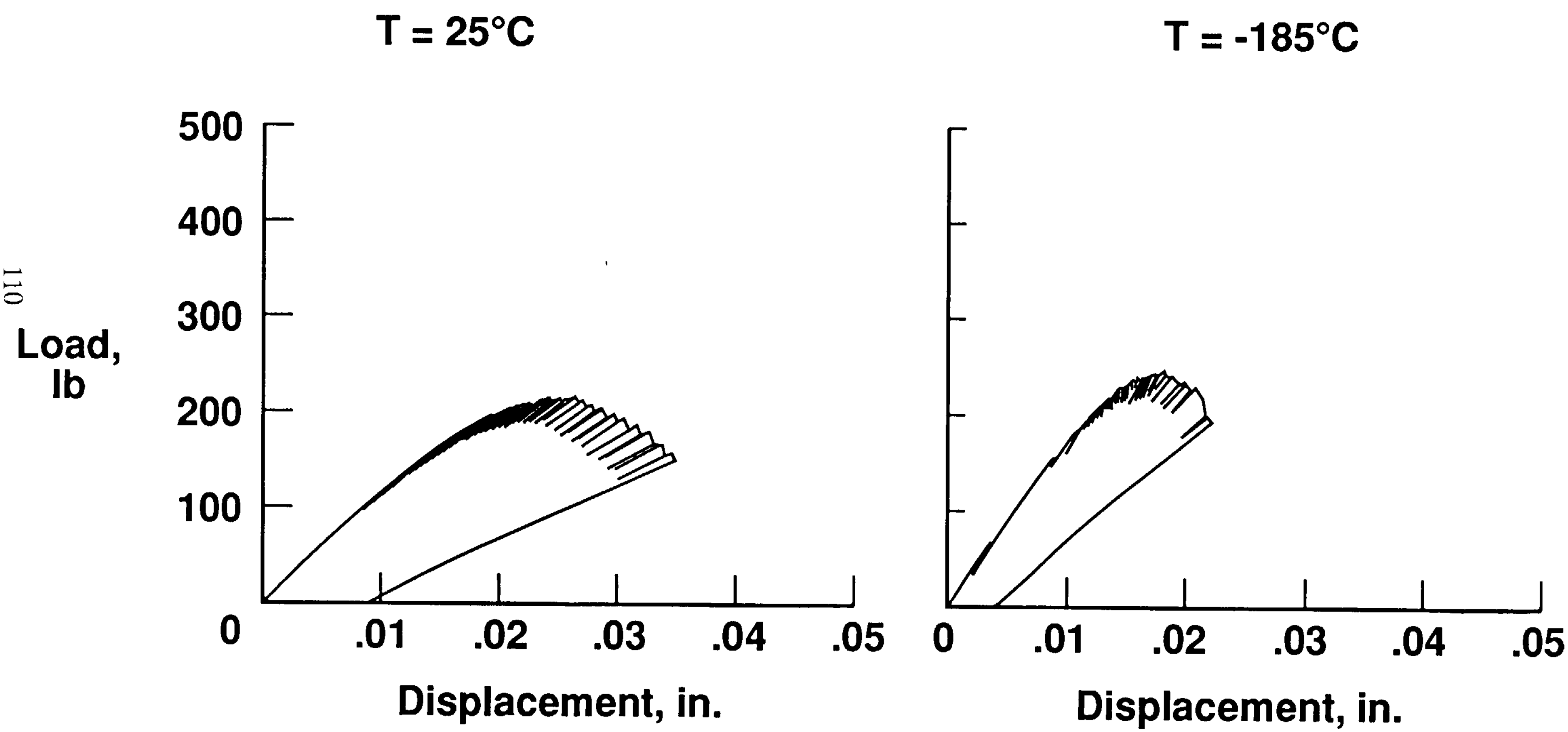
LOAD VERSUS DISPLACEMENT CURVES FOR 0.063 IN. 2090+In-T6 SPECIMENS AT 25°C AND -185°C



lvsdc6

Fracture of 2090 and 2090+In Alloys at Cryogenic Temperatures

SUMMARY

- In additions to 2090-based alloys increase T_1 number density, increase σ_{ult}, and no change in σ_{ys}
- Fracture in Alcoa 2090-T81 is primarily characterized by delamination and transgranular shear at both 25°C and -185°C
  Increase in toughness at -185°C associated with an increased level of delamination
- At 25°C the toughness of 2090+In-T6 is low, due to subgrain boundary precipitates, and characterized by intersubgranular fracture
- At -185°C the toughness of 2090+In-T6 is higher and there is a change in fracture mode from solely intersubgranular to intersubgranular with delaminations and transgranular shear

Fracture of 2090 and 2090+In Alloys at Cryogenic Temperatures

ISSUES

- Identify subgrain boundary particles and associated PFZ in 2090+In-T6
  Determine if In additions promote subgrain boundary precipitation

- Attempt to increase the toughness of 2090+In-T6 using modified aging treatments

- Determine the effect of stress state for the delamination/transgranular shear and intersubgranular fracture modes in 2090+In-T6 and 2090-T81

- Examine the mechanisms to account for the observed change in fracture mode of 2090+In-T6 at -185°C